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Trauma in pregnancy: A narrative review of the current literature

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ABSTRACT

Introduction: Trauma accounts for nearly half of all deaths of pregnant women. Pregnant women have distinct physiologic and anatomic characteristics which complicate their management following major trauma.
Objective: This paper comprises a narrative review of the most recent literature informing the management of pregnant trauma patients.
Discussion: The incidence of trauma during pregnancy is 6–8%. The focus of clinical assessment must be on the mother, starting with the primary survey. During airway management, clinicians should consider early intubation if necessary and utilize gastric tubes to minimize the risk of aspiration. Pregnant women experience progesterone-mediated hyperventilation, and normal PaCO2 levels may portend imminent respiratory failure. Clinicians should utilize left lateral tilt in hypotensive pregnant women to displace the uterus off the inferior vena cava. Ultrasonography is an attractive imaging modality for pregnant women which is specific for ruling in intraabdominal hemorrhage but not sufficiently sensitive to exclude this diagnosis. Clinicians should not hesitate to order computed tomography imaging in unstable patients if there is diagnostic ambiguity. Cardiotocographic monitoring simultaneously assesses uterine contractions and fetal heart rate and should last at least 4 h for pregnant women following even minor abdominal trauma if their fetus has achieved viable gestational age (approximately 24 weeks). In the event of cardiac arrest, peri-mortem cesarean section may improve outcomes for the mother and fetus alike. Unique specific complications include uterine rupture and placental abruption, which require emergent resuscitation and obstetrics consultation for definitive management. Emergency clinicians should maintain a low threshold for transfer to a tertiary care center given correlations between even isolated and relatively minor traumatic injuries with adverse fetal and maternal outcomes.
Conclusions: Trauma is a common cause of morbidity and mortality in pregnant women. Emergency clinicians must understand the evaluation and management of pregnant trauma patients.

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1. Introduction

1.1. Background

Trauma accounts for nearly half of all deaths of pregnant women [1]. Pregnant women have distinct physiologic and anatomic characteristics which complicate their management following major trauma [2,3]. These cases are further challenging to manage given the reality that many clinicians with extensive trauma management experience do not also commonly manage pregnant patients [4]. The presence of a fetus means there are effectively two patients, both of whom require evaluation and potentially treatment [5,6]. The priority in resuscitation of pregnant trauma patients is maternal stabilization [7,8].

1.2. Objective

This paper comprises a narrative review of the most recent literature informing the management of pregnant trauma patients. It will examine the literature relating to pregnant trauma epidemiology, physiology, maternal survey, pregnancy evaluation, and management.

2. Methods

We searched PubMed and Google Scholar for articles using a combination of the key words “pregnancy” OR “pregnant” AND “trauma.” We conducted the searches from database inception through 19 January 2024. We evaluated case reports and series, retrospective and prospective studies, systematic reviews and meta-analyses, and other narrative

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reviews. We also reviewed guidelines and supporting citations of included articles. We restricted the literature search to studies published in English. We decided which studies to include by consensus. We preferentially selected systematic reviews and meta-analyses followed sequentially by randomized controlled trials (RCTs), prospective studies, retrospective studies, case reports, and other narrative reviews.

Our initial search strategy yielded 201 articles. Of these, we excluded 33 papers focusing on non-physical trauma, 14 papers available only in non-English language, 9 papers relating to regular childbirth, and 5 papers examining long-term neuropsychological outcomes among children. We excluded 2 papers related to prevention strategies and 3 non-peer reviewed papers. We excluded 2 studies not examining clinical outcomes in living patients (one simulation study and one survey study) and one study examining long-term sequelae following remote trauma in pregnancy. This ultimately yielded 132 articles for inclusion in the review (Fig. 1).

3. Discussion

3.1. Epidemiology

3.1.1. Trauma incidence

The incidence of trauma during pregnancy is 6–8% [9]. Clinicians must entertain the possibility of pregnancy in all women as approximately 8% of all pregnant trauma patients determine their pregnancy status at the time of treatment for trauma [10]. Survival of pregnant trauma patients is generally higher than that of non-pregnant trauma patients after controlling for confounders, though trauma is the leading non-obstetric cause of death in pregnancy [11]. In the California Birth Registry from 2007 to 2011, delivery in the setting of recent trauma was associated with an increased risk of adverse outcomes including preterm birth and fetal demise [12]. Delivery during hospitalization is associated with worse outcomes than subsequent delivery after controlling for injury severity [13].

3.1.2. Domestic violence

Domestic violence is the most reported cause of trauma during pregnancy, affecting 4–8% of pregnant women. This incidence speaks to the importance of screening for domestic violence whenever caring for pregnant patients [14]. Screening must include the uncomfortable but critically important assessment for sexual assault [15,16]. These screenings are a particular challenge among adolescent patients. These patients may be disinclined to disclose concerns about domestic violence or even their pregnancies due to power and age differential with their partners. Maintaining patient confidentiality is a particularly important consideration for these patients [17].

Immigrant patients are another important population with unique management challenges. These patients may fear retribution from both partners and law enforcement. Language barriers may make history gathering challenging among immigrant women. Moreover, these patients may have unique health challenges due to infectious diseases endemic to their countries of origin. Adequate interpretation is imperative for treating these patients [18]. Furthermore, as with all pregnant women, screening ideally occurs using validated tools in a private setting without partners present [19,20].

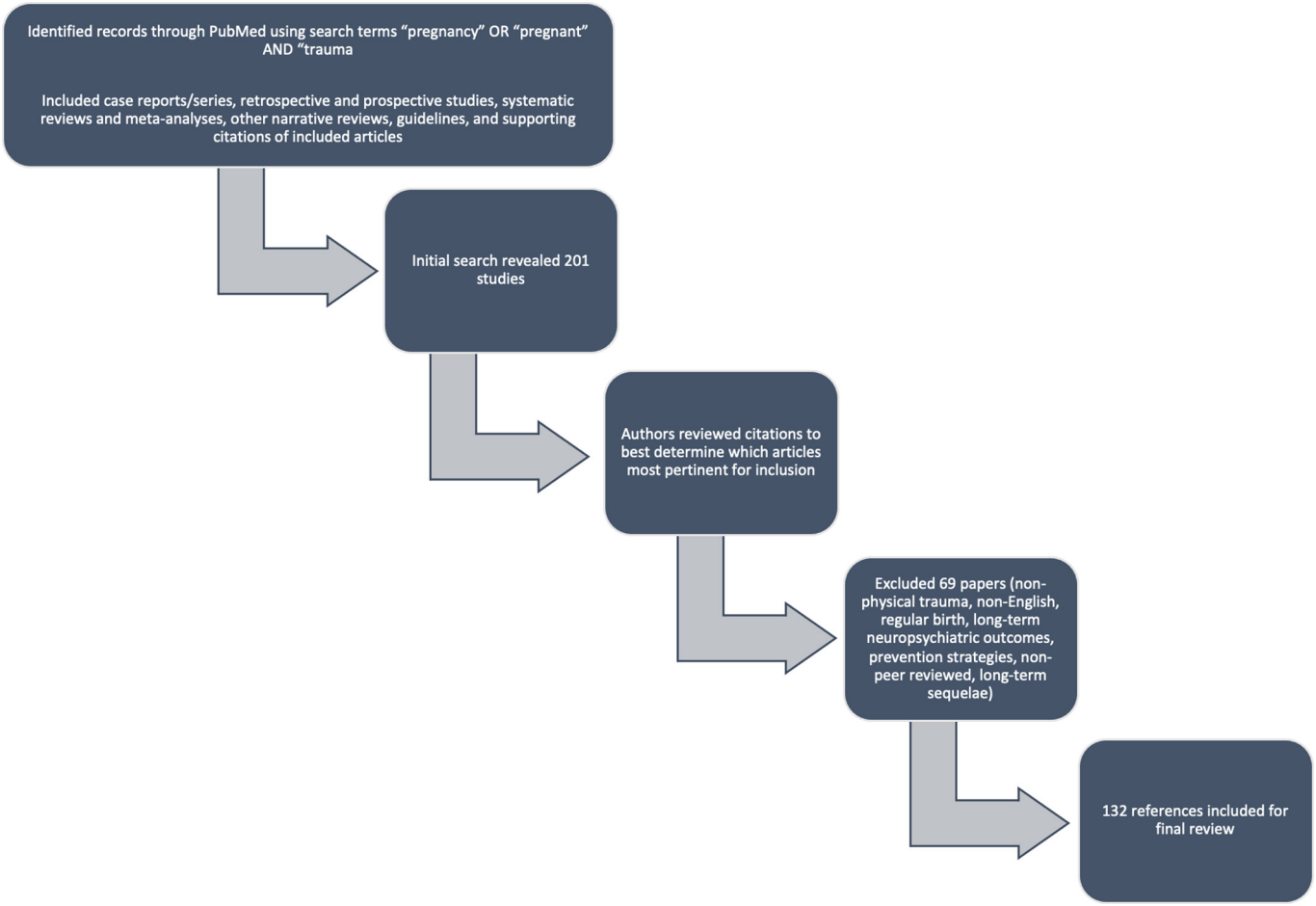
Identified records through PubMed using search terms "pregnancy" OR "pregnant" AND "trauma
Included case reports/series, retrospective and prospective studies, systematic reviews and meta-analyses, other narrative reviews, guidelines, and supporting citations of included articles
Initial search revealed 201 studies
Authors reviewed citations to best determine which articles most pertinent for inclusion
Excluded 69 papers (non-physical trauma, non-English, regular birth, long-term neuropsychiatric outcomes, prevention strategies, non-peer reviewed, long-term sequelae)
132 references included for final review

Fig. 1. Flow diagram for study inclusion.

3.1.3. Other mechanisms of injury

Other common mechanisms of injury include motor vehicle collisions (MVCs) [21] and falls [22,23]. Among MVC patients, unrestrained patients are at higher risk of maternal injuries and fetal death [24]. The specific distribution of mechanisms of injury is setting specific: in developing settings, some replicate the finding of a plurality of patients experiencing domestic violence [25] while others report MVCs as the most common mechanism of injury [26]. While some individual studies report relatively low risk of injuries among pregnant women following MVCs [27], a systemic review reported a higher risk of placental abruption with maternal death with MVCs as compared to other mechanisms of injury [28]. These data highlight the critical importance of proper seatbelt use by pregnant women as a preventive measure [29].

3.1.4. Prognostication

Identifying predictors of maternal and fetal outcomes is an important objective for clinicians. Multiple observational studies have found no association of most measured clinical variables with patient outcomes, including mechanism of injury or maternal demographics [30,31]. Conversely, studies looking at injury severity score (ISS) have generally found this measure predictive of outcomes [32]. A single center retrospective cohort study including 900 pregnant patients found that ISS ≥ 9 was associated with adverse maternal and fetal outcomes [33]. A second retrospective cohort analysis of 119 pregnant women admitted for traumatic injuries similarly reported increased odds of adverse maternal and fetal outcomes with ISS ≥ 8 [34]. A third observational study of 80 injured pregnant patients identified ISS ≥ 8 and non-viability as independent risk factors for fetal demise [35].

Another important association with adverse outcomes is duration of pregnancy. A single-center retrospective analysis of 292 pregnant patients found that, in addition to ISS > 2, trauma in the third trimester was associated with adverse obstetrical outcomes [36]. A second observational study of 139 patients found that nearly half (46%) of pregnant trauma patients sustained injuries in their third trimester [37]. Finally, an observational study of 61 pregnant women hospitalized after trauma found only maternal hypotension and low fetal heart rate to be associated with adverse pregnancy outcome [38].

It is possible the lack of associations for other variables reflect the relatively mild nature of the injuries of many pregnant patients reported in the literature [39]. However, arguing against this position is that population-based datasets have demonstrated that even minor injuries to be associated with increased odds of preterm labor [40]. Of maternal complications during delivery associated with trauma, up to 62% are the result of minor rather than severe traumatic injuries [41]. Given the possibility of even minor injuries to portend adverse outcomes, it is imperative that clinicians follow a careful approach to the evaluation and monitoring of all pregnant trauma patients [42].

3.2. Clinical assessment

The focus of clinical assessment must be on the mother to optimize outcomes for mother and child alike. Mendez-Figueroa et al. argue that "pregnancy should not lead to underdiagnosis or undertreatment of trauma due to unfounded fears of fetal effects." [43] Indeed, a retrospective registry analysis of 173 pregnant trauma patients in the United Kingdom reported no cases of fetal survival with maternal death [44]. For this reason, much of the clinical assessment for pregnant women resembles that for non-pregnant patients [45,46]. As with all trauma patients, the resuscitation of pregnant trauma patients should start with the primary survey (Table 1) [47,48]. This includes assessments of the patient's airway, breathing, circulation, disability (neurologic status), and complete exposure of the patient [49,50]. The unique anatomy and physiology of pregnancy have important implications for each step of the primary survey [51]. Consequently, emergency clinicians should consider early consultation of obstetricians and other specialists in the care of these patients [52,53].

Table 1
Physiologic and vital sign considerations in pregnancy.

Organ system	Effects of pregnancy	Implications for trauma management
Pulmonary	-Progesterone-mediated hyperventilation with respiratory alkalosis -Increased oxygen demand due to fetus	-Higher susceptibility to acidosis due to fall in plasma bicarbonate -$PaCO_2$ of 30 mmHg can be normal; $PaCO_2$ of 35–40 mmHg may portend respiratory failure -Increased risk of hypoxia
Cardiovascular	-Higher cardiac output due to rise in blood volume and heart rate with decreased vascular resistance -Potential compression of inferior vena cava by gravid uterus in the supine position	-Baseline heart rate 10–15 beats per minute faster than pre-pregnancy -Susceptible to hypotension in supine position
Gastrointestinal	-Progesterone-mediated gastroesophageal sphincter relaxation -Progesterone-mediated delayed gastric emptying -Increased intra-abdominal pressure due to gravid uterus	-Increased aspiration risk
Hematologic	-Increase in blood volume with concomitant rise in fraction of plasma volume -Increase in concentrations of fibrinogen and other clotting factors	-Decreased baseline hematocrit (32%–42%) -Pregnant patients can lose up to 1500 mL before showing signs or symptoms of hypovolemia -Pro-coagulant state
Musculoskeletal	-Widening of the symphysis pubis by 4–8 mm in late pregnancy -Widening of the sacroiliac joints	-Altered normal parameters for interpretation of pelvic radiography
Neurologic	-Eclampsia is a known complication of late pregnancy	-Risk of seizures due to non-traumatic etiologies

3.2.1. Airway

As with all trauma patients, clinicians should maintain cervical spine immobilization in patients who may have sustained spinal cord trauma [54]. Challenging airway characteristics that may occur in pregnancy include mucosal edema. Clinicians should address these challenges by developing a difficult airway management plan to include airway adjuncts such as bougie, video laryngoscopy, laryngeal mask airway, and set-up for cricothyrotomy [55]. The fetus is sensitive to maternal hypoxia, and prevention of fetal hypoxia requires aggressive maternal pre-oxygenation and potentially apneic oxygenation. Consequently, clinicians should have a low threshold to intubate early during maternal resuscitation [56,57].

An additional challenge posed by pregnant women includes decreased gastroesophageal sphincter function. This places these patients at increased risk of aspiration [58]. Placement of a nasogastric or orogastric tube early in the management of unconscious patients may minimize the risk of aspiration.

3.2.2. Breathing

Pregnant women experience progesterone-mediated hyperventilation with respiratory alkalosis and increased oxygen demand due to fetal requirements. These patients often have a baseline PaCO2 of 30 mmHg in later stages of pregnancy [59]. Importantly, a "normal" PaCO2 of 35–40 mmHg may portend impending respiratory failure. Mechanical ventilation settings should target PaCO2 levels of approximately 30 mmHg in late pregnancy [55].

Other breathing considerations include pulmonary implications of physiologic changes during pregnancy. Pregnant women are at unique risk of pulmonary complications following blunt chest trauma; one case report supports the use of prone positioning to optimize

oxygenation [60]. Pregnant women also experience superior displacement of the diaphragm [61]. As a result, clinicians should consider chest tube thoracostomy placement in the third or fourth intercostal space rather than the fifth intercostal space commonly used in non-pregnant patients.

3.2.3. Circulation

Due to the intravascular volume expansion of pregnancy, women may lose up to 20% of the blood volume before showing signs or symptoms of hypovolemia [1]. Patients over 20 weeks gestational age should undergo 30–45° + left lateral tilt to displace the uterus off the inferior vena cava [62,63]. This may be completed by placing towel rolls or premade elevators under the right hip or under the backboard on the right side if in-line stabilization is necessary. In patients requiring emergent resuscitation, manual left uterine displacement is recommended rather than lateral tilt in order to maximize chest compression effectiveness [64]. In patients for whom hypotension persists despite these maneuvers and they remain too unstable for surgical intervention, uterine compression both internally (via insertion of a uterine Bakri balloon) and externally may achieve temporary stabilization [65]. In first trimester patients in apparent hemorrhagic shock, clinicians should be aware of the rare possibility of a ruptured heterotopic pregnancy as a contributing etiology for patient decompensation. Such pathology may only be apparent upon exploratory laparotomy [66]. Some authors advise against vasopressors given the risk of diminishing uterine blood flow [59].

3.2.4. Secondary survey

Following the primary survey, the secondary survey is essential to identify other injuries. This comprises a complete history and physical examination. History including date of expected delivery, complications of pregnancy, previous obstetric history, last menstrual period, mechanism of injury, and if the patient was in an MVC, whether the patient was restrained and a seat belt worn appropriately. While seat belts reduce the risk of maternal adverse outcomes, incorrect position of the belt (i.e., worn across the gravid uterus instead of below it) increases the risk of uterine rupture and other abdominal injuries [67]. Clinicians should pay particular attention in history taking to explore correlates with adverse outcomes. These include demographics such as young age, African-American ethnicity, and Hispanic ethnicity. These observational associations are not capable of establishing causation, and the likelihood for these associations is likely multifactorial. Potential reasons include socio-economic challenges and living circumstances placing this population at generally higher risk of trauma together with relatively poorer access to healthcare in general and prenatal care specifically [68].

Clinicians should also explore the possibility of domestic abuse, illicit substance and alcohol use, or intentional self-harm or overdose [69]. Approximately half of pregnant women in one cohort tested positive for intoxicants [70]. Discerning the mechanism of injury is important for both therapy and prognosis with penetrating injuries placing the fetus at especially high risk for adverse outcomes [71,72], particularly in the case of gunshot wounds [73]. A retrospective analysis of 321 pregnant trauma patients admitted to level one trauma centers revealed higher maternal and fetal mortality with penetrating as compared to blunt abdominal trauma [74]. That said, blunt trauma can lead to its own unique sequelae such as rupture of ectopic pregnancy [75].

Physical examination should include a careful assessment of the gravid uterus to assess for size and contractions. The distance between the symphysis pubis and the uterine fundus in centimeters is a reasonable approximation of the weeks of gestation. Heights halfway between the umbilicus and the xyphoid process likely translate to sufficient gestational age for fetal viability [76]. That said, guidelines vary in their assessment of what constitutes the age of fetal viability from as low as 20 to as high as 24 weeks [77]. In situations of ambiguity regarding gestational dates or limits of viability, a conservative approach erring on the side of resuscitation is to assume viability of any fetus with the uterine fundus at the level of the umbilicus.

Also critical is the vaginal examination. Initial evaluation should include an external examination for bleeding. However, an internal vaginal examination should be avoided if the patient is over 20 weeks gestational age until placenta previa is excluded [78]. If possible, the vaginal examination should be performed with the obstetric specialist. A constellation of vaginal bleeding or discharge, abdominal pain, contractions, uterine rigidity, and hypotension are suggestive of placental abruption or uterine rupture [79]. Although small studies exist showing no association between these symptoms and fetal or maternal outcomes [31], other studies highlight that these symptoms likely portend actionable pathology and require careful attention by the emergency clinician for obstetrics consultation [80]. Nitrazine paper and the ferning test can assist clinicians in assessing vaginal discharge to ascertain whether rupture of membranes has occurred [78]. Any signs of ruptured membranes or impending labor in the setting of fetal viability mandates obstetrics consultation for further monitoring and management.

Clinicians should also evaluate for signs of pre-eclampsia. These signs include hypertension, pulmonary edema, neurologic findings, and visual deficits [78]. Clinicians should appreciate that neurologic deficits or seizures in a pregnant patient with head trauma may represent either intracranial hemorrhage or eclampsia.

3.2.5. Laboratory studies

Clinicians should consider several laboratory tests unique to pregnant women in addition to standard studies obtained on trauma patients (Table 2). First, all pregnant trauma patients should undergo Rh(D) testing. Women who are Rh(D) negative should receive 300 micrograms of Rh(D) immune globulin to prevent isoimmunization in the event the fetus is Rh(D) positive [81,82]. These women should ideally also undergo Kleihauer-Betke testing to quantify fetomaternal hemorrhage and so determine whether additional doses of immune globulin are necessary. However, the existing literature does not indicate that Kleihauer-Betke testing serves additional prognostic information for the mother [83]. In fact, retrospective observational data indicate that flow cytometry testing, a method to quantify transplacental hemorrhage which may be even more accurate than Kleihauer-Betke testing, is not reliably associated with other maternal or fetal outcomes [84].

Finally, serum alpha-fetoprotein is a laboratory study that may offer prognostic information for pregnant trauma patients. Observational cohorts and case reports suggest an association between elevated serum alpha-fetoprotein levels (>1000 ng/mL) and adverse pregnancy outcomes including fetal injury, fetal death, and intrauterine hemorrhage [85,86]. If available, clinicians should consider obtaining this study in pregnant trauma patients and closely observing or further evaluating patients with elevated levels.

3.2.6. Imaging studies

Ultrasonography is an attractive imaging modality for pregnant women given that it does not expose these patients to radiation [87]. The focused assessment with sonography for trauma (FAST) examination remains the cornerstone of diagnostic ultrasonography in trauma. However, negative ultrasonography results do not exclude

Table 2
Baseline laboratory considerations in pregnancy.

- Reduced hemoglobin and hematocrit due to increased plasma volume
- Increased white blood cell count
- Decreased platelet count
- Increased D-dimer, fibrinogen
- Glomerular filtration rate increases by up to 60%
- Decreased BUN and creatinine
- Decreased serum bicarbonate
- Decreased PaCO2
- Increased erythrocyte sedimentation rate

intrabdominal bleeding [88,89]. Using computed tomography (CT) as the reference standard, among 119 pregnant trauma patients, one study found the specificity of ultrasonography for intraabdominal hemorrhage was 91%, but the sensitivity was only 11%. Consequently, the study authors state that ultrasonography adds questionable negligible diagnostic information by likelihood ratios; however, we believe this modality may be useful if positive. [90] Magnetic resonance imaging (MRI) is another non-radiating imaging modality that may be useful for characterizing placental injuries and hematomas [91]. That said, relatively little literature exists speaking to the utility of emergent MRI as part of the resuscitation of trauma patients, likely owing to the increasing ubiquity and accuracy of ultrasonography. While MRI and ultrasound both spare the mother and fetus radiation exposure, CT with intravenous contrast remains the imaging modality of choice for intraabdominal injuries associated with trauma as well as placental abruption [92,93]. Clinicians should also not hesitate to order CT imaging in unstable patients if there is diagnostic ambiguity [94,95]. CT may furthermore be necessary to identify traumatic injuries to the fetus itself [96].

3.3. Fetal assessment

Foremost among the challenges in treating pregnant trauma patients is the need to simultaneously treat two patients [97,98]. Trauma places the unborn fetus at increased risk of both immediate mortality and delayed morbidity. Preterm delivery is the most common pregnancy complication affecting the fetus in observational studies of pregnant women admitted for trauma [99]. A retrospective cohort study of 188 pregnant trauma patients reported premature delivery (11%), fetal demise (7%), and stillbirths (5%). Risk factors for fetal loss include maternal death, severe abdominal injury, hemorrhagic shock, and maternal injury severity [100]. Also reported in the literature is single fetal deaths in twin pregnancy [101]. Infants born at the time of trauma have significantly more complications and worse outcomes compared to those born at term. Overall, 66% of children born at the time of trauma experienced some form of adverse outcome [102].

For these reasons, fetal and uterine monitoring is mandatory for those patients whose fetuses have achieved viability [103]. Cardiotocographic monitoring simultaneously assesses uterine contractions and fetal heart rate. Prior to viability, fetal assessment should include measurement of fetal heart rate by Doppler or ultrasound (normal is 120–160 beats per minute). Past the date of viability, pregnant women sustaining even ostensibly minor abdominal trauma should undergo at least 4 h of continuous monitoring of fetal heart rate and uterine contractions. Concerning findings include abnormal fetal heart rate, decreased fetal heart rate variability, or marked fetal heart rate decelerations [104].

Best practice is to protocolize this monitoring as part of the resuscitation of all pregnant trauma patients given a lack of variables identified in the literature to reliably identify patients at greatest risk of fetal complications [105,106]. That said, observational studies of pregnant patients following minor trauma report generally excellent prognosis and poor predictive capacity for clinical characteristics to predict adverse outcomes [107,108]. A chart review study of 946 pregnant patients who sustained minor trauma (defined as ISS < 3) demonstrated no differences in outcomes between patients hospitalized for 24-h monitoring versus those who refused hospitalization [109]. Similarly, a retrospective study comparing 512 pregnant patients at ≥23 weeks gestation sustaining trauma deemed not life-threatening or requiring surgery versus 1024 non-trauma pregnant patients found no differences in the risk of adverse pregnancy outcome [110]. While prevailing opinion generally recommends at least 4 h of monitoring for all patients, those having sustained only minor injuries are likely candidates for discharge following this initial observation period. If there are risk factors for fetal loss of abruption, monitoring for 24 h or admission is recommended. This includes >4 contractions per hour, high risk mechanism of injury, worrisome fetal monitor strip, persistent uterine tenderness, rupture of membranes, or vaginal bleeding.

3.4. Management

3.4.1. Cardiopulmonary resuscitation and perimortem cesarean section

Cardiopulmonary resuscitation with chest compressions is thought to be less effective in pregnant patients due to aortocaval compression by the uterus [111]. Peri-mortem cesarean section, also known as resuscitative hysterotomy, may improve outcomes for the mother and fetus alike by alleviating this compression, even if the fetus is non-viable [112,113]. The sooner this procedure occurs after onset of cardiac arrest, the more optimal the outcomes [114]. The procedure must start within 4 min and be complete no later than 5 min after onset of maternal cardiac arrest (Table 3) [115,116]. Indications include maternal cardiac arrest without return of spontaneous circulation (ROSC) within 4 min and estimated gestational age > 20–24 weeks. Contraindications include estimated gestational age < 20 weeks or ROSC within 4 min of arrest.

Case series exist reporting the use of resuscitative endovascular balloon occlusion of the aorta (REBOA) for atraumatic hemorrhagic shock such as that due to placenta abruption [117,118]. However, we did not identify any such reports for pregnant women experiencing traumatic mechanisms.

3.4.2. Management

Case reports indicate that if pregnant patients can survive their initial resuscitation, they are likely to have positive outcomes with definitive surgical management for their injuries [119]. Foremost among required interventions given the frequency of blunt abdominal trauma in this population will be to address intraabdominal hemorrhage. Reports exist of the successful use of splenic embolization to control hemorrhage from splenic injuries as a comparatively less invasive management technique [120,121]. For patients with significant uterine

Table 3
Resuscitative hysterotomy.* **

Procedure
1. Widely cleanse the entire abdomen.
2. Get into the abdomen:
- Make a midline incision from the uterine fundus to pubic symphysis through the skin and fat with a scalpel (avoid the umbilicus if possible).
- Dissect through the peritoneum with scalpel or scissors and use blunt-ended scissors to extend vertically.
- Use retractors or gloved hands.
3. Get into the uterus:
- Make a 2 cm incision in the lower part of the uterus with a scalpel.
- Insert two fingers into the uterine incision between the fetus and the myometrium; extend incision vertically to the fundus with scissors.
- If placenta is in the way, cut through it.
4. Get fetus out:
- Place a hand inside the uterus to find the fetal head and deliver the fetus. Avoid grasping the fetus around the abdomen; fundal pressure may assist.
5. Cord and placenta:
- Clamp and cut the cord immediately; hand neonate to neonatal resuscitation team.
- Place gentle pressure on the umbilical cord and remove placenta completely.
- Administer uterotonic agent.
6. Pack wound with sterile towels/packing while waiting for obstetrics/surgery specialist.
7. May close with skin stapler or locking suture.
8. Continue resuscitation.

* Equipment: C-section or laparotomy surgical kit, thoracotomy kit, betadine or chlorhexidine, sterile gown/gloves, skin stapler. If surgical kit not available, obtain scalpel, large scissors, hemostats, sterile gauze.

** Prior to procedure: Call for assistance (obstetrics/surgery, anesthesia, respiratory therapist, NICU or pediatrics), perform manual left uterine displacement, secure maternal airway, obtain IV access, place on cardiac monitor, place foley catheter (reduced risk of bladder injury with drained bladder), ready equipment for neonate, divide team into maternal and neonate resuscitation teams, have blood products ready.

contractions, tocolysis should be considered in conjunction with obstetric specialist consultation. This may include nifedipine 30 mg by mouth as a loading dose or magnesium sulfate 4 g intravenous.

Orthopedic injuries are relatively rare in pregnancy but portend additional complications and adverse outcomes. A single center observational study compared 65 pregnant trauma patients with orthopedic injuries versus 990 patients without and determined that the former had an increased risk of preterm delivery, placental abruption, and perinatal mortality [122]. The most common orthopedic injuries are ankle fractures [123]. Orthopedic injuries requiring surgical intervention will generally proceed as for non-pregnant patients [124]. That said, surgical decision making may deprioritize minimally invasive fixation techniques given relatively increased radiation exposure requirements. Pelvic fractures place the mother and fetus at particularly high risk of adverse outcomes and require immediate attention. The range of options available to treat these injuries is the same as for non-pregnant patients and include pelvic binder followed by laparotomy with retroperitoneal packing and external fixation versus angiography [125].

3.5. Specific complications

3.5.1. Uterine rupture

Uterine rupture is a life-threatening tear of the uterus, which may result in the fetus entering the peritoneal cavity. Patients most often present with persistent abdominal pain and evidence of peritonitis, vaginal bleeding, hemodynamic instability, loss of fetal station, fetal bradycardia, and a palpable uterine defect. Imaging includes CT, MRI, or US, which may reveal a uterine defect, a fetus within the peritoneal cavity, free intraabdominal fluid, herniated amniotic sac, and empty uterus (Fig. 2). Management includes emergent resuscitation and obstetric specialist consultation for hysterotomy [126,127].

3.5.2. Placental abruption

Placental abruption is the premature separation of the placenta from the uterus. This most often occurs spontaneously but can occur with any form of trauma past 15 weeks gestion [114,128]. It is the most common cause of fetal death in patients with blunt trauma, but there is no association with the severity of trauma with the likelihood of placental abruption [129]. Patients typically present with painful, dark vaginal bleeding, though bleeding may not be apparent in 30% of patients, and up to 20% have no pain. Patients may be hemodynamically unstable and also present with contractions or uterine hypertonicity, nausea and vomiting, back pain, fetal distress (tachycardia, bradycardia, decelerations, loss of variability), and increased fundal height. Pelvic US is specific but lacks the necessary sensitivity to exclude the diagnosis [130,131]. CT possesses a sensitivity approaching 100% for diagnosis of placental abruption (Fig. 3) [92]. Fetal monitoring is also recommended. Management includes resuscitation with blood products if necessary and emergent obstetric specialist consultation [128]. For patients with abruption occurring between 23 weeks and 36 + 6 weeks gestation, a dose of antenatal corticosteroids to improve fetal lung maturity is recommended such as betamethasone 12 mg intramuscular every 24 h for 2 doses or dexamethasone 6 mg intramuscular every 12 h for 4 doses.

3.6. Disposition

The Western Trauma Association algorithm offers a basis of criteria to guide the safe discharge of pregnant trauma patients. These include maternal hemodynamic stability, confirmation of normal fetal heart tones, attending to injuries, and consultation of obstetrics. These guidelines further recommend observation of the mother and fetus for at least 6 h [47]. These guidelines are broadly consistent with those of the Society of Obstetricians and Gynecologists of Canada (SOGC), though the latter contends only 4 h of monitoring are necessary. The latter further recommends that all pregnant women with a viable pregnancy undergo an obstetrical ultrasound prior to discharge from the hospital [78]. Importantly, emergency clinicians should maintain a low threshold for transfer to a tertiary care center given correlations between even isolated and relatively minor traumatic injuries with adverse fetal and maternal outcomes [132].

4. Conclusions

Trauma is a common cause of morbidity and mortality in pregnant women. The focus of resuscitation efforts must be on the mother, starting with the primary survey. Early obstetrics consultation is prudent when there are signs of impending labor in the setting of fetal viability (≥24 weeks gestation), and emergency clinicians should maintain a low threshold for transfer to a tertiary care center.

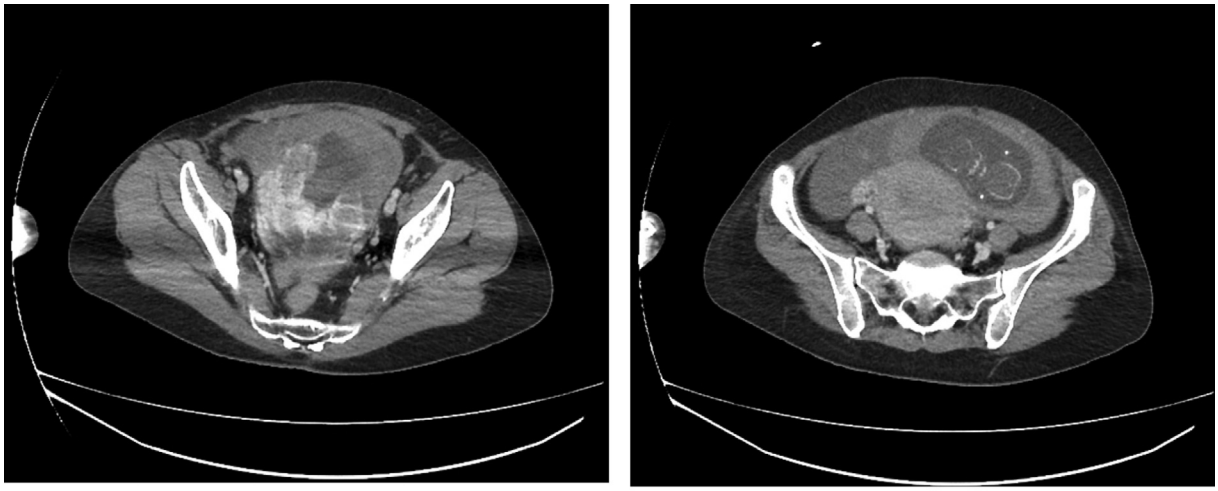

Fig. 2. CT demonstrating uterine rupture. There is an anterior median uterine wall defect (A) with protrusion of the amniotic sac and fetus into the peritoneal cavity (B), as well as free intra-abdominal fluid. Case courtesy of Mojtaba Felegari, Radiopaedia.org, rID: 180297.

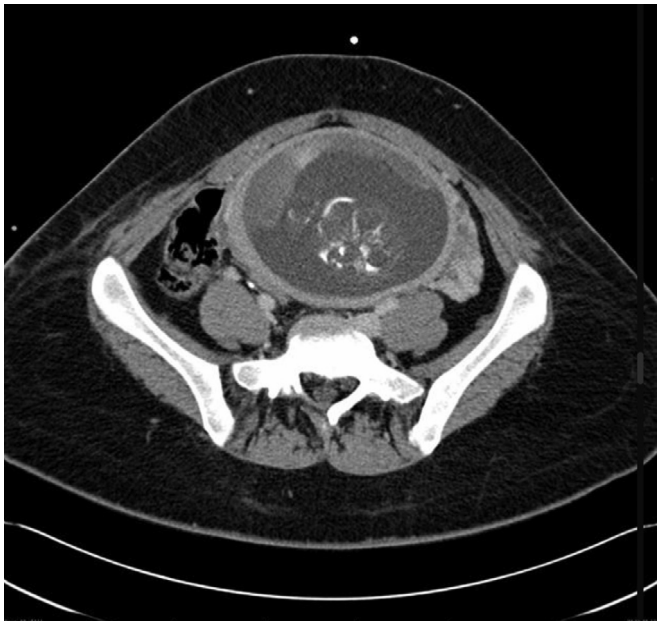

Fig. 3. CT demonstrating a heterogeneous anterior placenta with significant areas that do not enhance, suggesting placental abruption. Case courtesy of RMH Core Conditions, Radiopaedia.org, rID: 27758.

CRediT authorship contribution statement

Michael D. April: Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Formal analysis, Conceptualization. **Brit Long:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Conceptualization.

Declaration of competing interest

None.

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MDA and BL conceived the idea for this manuscript and contributed substantially to the writing and editing of the review. This manuscript did not utilize any grants, and it has not been presented in abstract form. This clinical review has not been published, it is not under consideration for publication elsewhere, its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder. This review does not reflect the views or opinions of the U.S. government, Department of Defense, Defense Health Agency, U.S. Army, U.S. Air Force, or SAUSHEC EM Residency Program.

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